Reducing Quadrature Errors with CutMesh MPM

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The Material Point Method (MPM) is a powerful numerical tool for modeling large deformation problems in solid mechanics. It is well understood that as material points move freely throughout the computational domain, the accuracy of the simulated stresses and strains degrade as a result of increasing quadrature error. Additionally, when moving between adjacent cells, material points exhibit cell crossing error. Cell crossing error is responsible for large numerical perturbations that further reduce the simulation's overall accuracy and stability. Others have shown that cell crossing error is a consequence of combining the following: (i) inaccurate volume integration, (ii) point-wise representation of the material point density, and (iii) basis functions with discontinuous gradients at cell boundaries. There are many existing variations of the MPM which address the point-wise representation of density or the discontinuous gradients at cell boundaries. This work employs a novel approach to address inaccurate volume integration. The proposed method reduces quadrature error by recomputing optimal integration weights throughout the simulation as material points move to new positions. By addressing the inaccurate volume integration, cell crossing errors are considerably reduced. Numerical improvements are illustrated by comparing the displacement, strain, and stress errors for a uniaxial elastic bar problem between this newly proposed formulation and the standard MPM.

Wilson, P., Wüchner, R., & Fernando, D. (2021). Distillation of the material point method cell crossing error leading to a novel quadrature-based C0 remedy. *International Journal for Numerical Methods in Engineering*, 122(6), 1513-1537.